40 Gb/s Wavelength Division Demultiplexing with a PhC Filter

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Abstract: *We have designed and fabricated a photonic crystal filter intended for demultiplexing in wavelength division domain. This device is single-mode, the total insertion losses are about 12dB and the channel isolation can exceed 25dB. Non return to zero signal at 40Gb/s have been successfully filtered with no penalty in the bit error rate analysis. The device is cascadable to form a multi-channel demultiplexer and can be tuned through an integrated, low power temperature controller.*

1. Introduction

High-quality and very small volume optical cavities are an attractive feature of the Photonic Crystal (PhC) technology [1]. That enables true single-mode resonators, e.g. with very large free-spectral range, which are therefore suitable for integrating filters, particularly for WDM applications [2].

Single [3] and multi-channels [4,5] optical filters based on this technology have been demonstrated. Drop efficiencies exceeding 50% (relative to the bus) and cross-talk rejection better than 25dB have also been reported.

Here we report the elementary bricks in order to achieve a WDM filter knowing a low loss drop filter, a tunable filter and the measurement of the transmission and filtering of NRZ data signal at 40 Gb/s.

2. The Photonic Crystal Technology

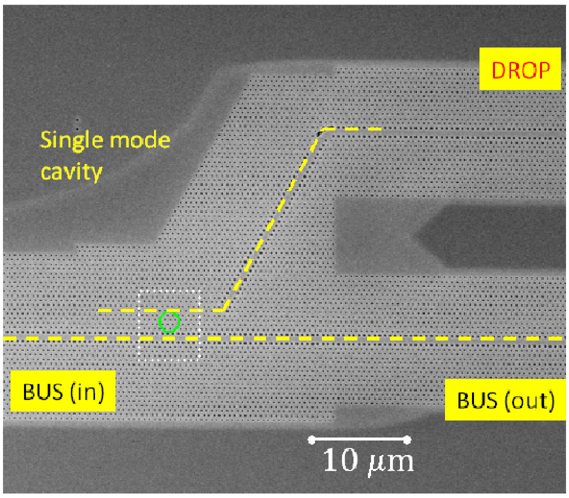

Fig. 1. SEM image of the WDM filter with one drop channel. The white dashed line indicates the area where the single mode resonant cavity is located.

Our devices are PhC chips based on the III-V technology. That enables the future integration of light emitting devices, with the potential of ultra-low power consumption, as demonstrated by the NTT group [6]. On this platform, we have demonstrated a processing quality comparable to Silicon, e.g. we achieved a Q-factor exceeding one million [7].

In order to reduce the total insertion losses, we have improved the fiber to PhC coupling using integrated mode adapters (loss is about 2.5 dB per face in TE mode) and we have optimized the cavity to the waveguide coupling in order to reach the optimal drop efficiency, namely 50% in our 3-ports, single resonator design, shown in fig. 1, representing our best result.

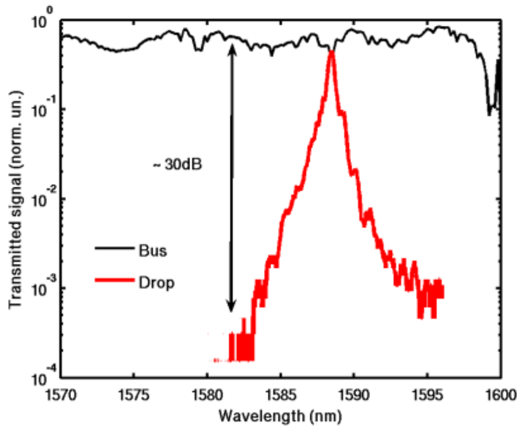

Fig. 2. Transmission through the drop and the bus channels, normalized to the maximum bus transmission.

We have measured the transmission through the bus and the drop channels and normalized to a common reference, that is the maximum transmission in the bus channel, as shown in fig. 2. The drop transmission is very close to 50% and the resonance follows the Lorentzian lineshape over more than 3 decades. Outside the resonance, the signal through the drop is below 30dB or not measurable all over the PhC waveguide transmission range, namely 50 nm. Finally, the total insertion loss, from the input fiber to the output fiber on the drop channel is about 12dB, thereby including fiber to PhC input and output coupling loss, propagation loss and the intrinsic drop efficiency.

3. Tuneability

On the same technological platform, but not so far the same sample, as shown in figure 1, we demonstrated the tunability of the resonator through integrated electric heaters. As a voltage is applied, the cavity resonance is tuned with a consumption of 0.7mW of electrical power per 1 nm of wavelength shift (Fig. 3).

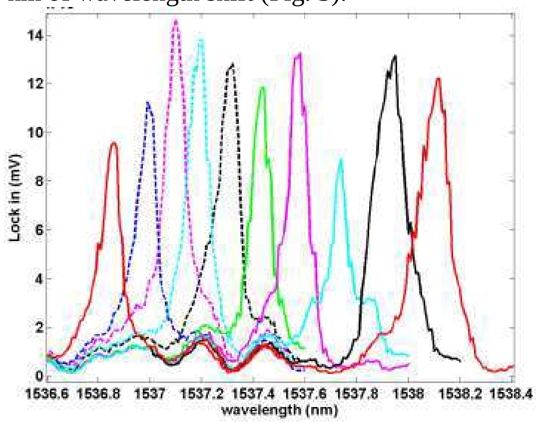

Fig. 3. Transmission of the filter as the resonance is tuned by an integrated heater.

The fluctuation observed here are related to residual reflection at the waveguide facets, due to imperfections in this particular sample, but which can be totally eliminated, as the perfect lorentzian shape in fig 2 shows. Finally, the tuneability range is expected to reach 10nm (here, the estimated temperature change is only a few degrees K so there is no issue with thermal stress.

4. Bit Error Rate measurements

The characterization of transmission of NRZ data signal at 42.7 Gb/s through a filter is also reported, although this involved an older and less optimized sample.

The bit error rate (BER) is measured for the bus and the drop channels as a function of the received power and is compared with the BER resulting from the signal directly input to the receiver with equivalent power level.

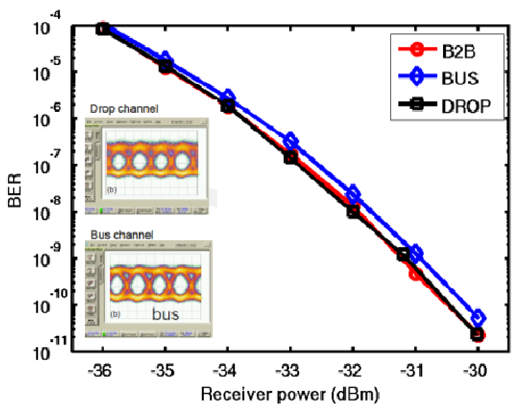

Fig. 4. Bit Error Rate measurement of the signal through the Bus and the Drop outputs and comparison with Back to Back at the same power level. Eye diagrams in the insert.

The result is reported in fig. 4, along with the eye-diagrams. No penalty can be attributed to the filter, as the three curves basically superimpose.

7. Conclusions

We have developed optical filters for wavelength domain demultiplexing based on a semiconductor photonic crystals technology. We have reported, although not yet in the very same sample, the achievement of a tunability, the lowering of the total insertion losses down to 12 dB, the reaching a drop efficiency up to 50% and 30 dB cross-talk isolation. In the first generation of this devices, we have performed BER measurements with data signal at 40Gb/s, showing not additional penalty after the transmission through the filter (both drop and bus channels). Furthermore, we estimate to 1 mW the electric power budget for accurately tuning our filter. The next step will consist in combining all these features on the same chip and demonstrate a tuneable multi-channel WDM demultiplexer.

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